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LEXINGTON, MASSACHUSETTS

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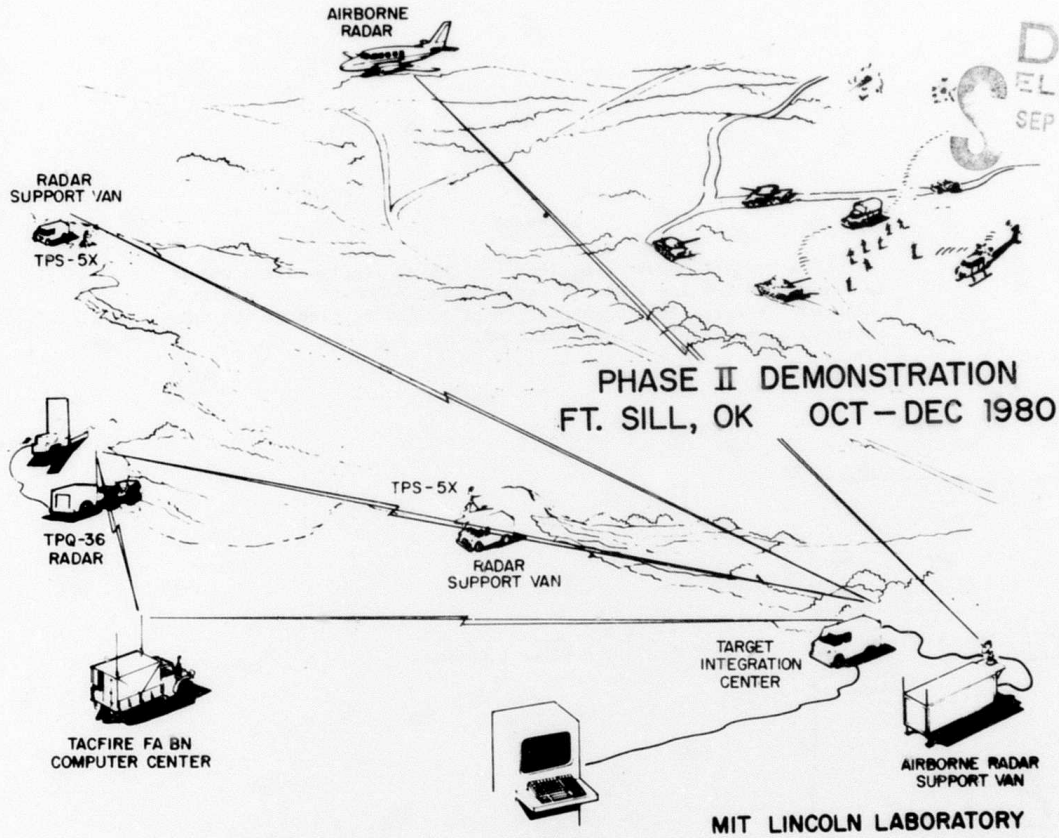
DARPA/ARMY NETTED RADAR PROGRAM



PHASE II DEMONSTRATION
FT. SILL, OK OCT – DEC 1980

MIT LINCOLN LABORATORY

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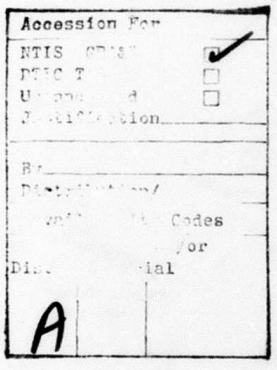
ABSTRACT

This Project Report describes the system configuration which is being used for the Phase II Netted Radar Demonstration currently under way at Fort Sill, Oklahoma. A brief description of the demonstration scenarios is also included.



SUMMARY

The DARPA/Army Netted Radar Program was initiated in 1977 to (1) develop modern radar processing and netting technology, and (2) demonstrate the operational advantages. In the Fall of 1978, a Phase I Demonstration was conducted at the Army Field Artillery Center, Ft. Sill, OK. The equipment for this Demonstration was two modified PPS-5 ground-based ground-surveillance radars, and a Target Integration Center (TIC) with one remote display. A simple two radar net was operated which showed the modified radar capability for automatic target acquisition and tracking, with remote control and display over a voice-grade radio link; also shown was the feasibility and benefits of netting and automatically integrating radar data. As a result of the Phase I Demonstration, the Field Artillery School initiated a ROC (Required Operational Capability) and an O&O (Operational and Organizational) concept for NURADS (Netted Universal Radar System).

A distributed netted sensor system combines data from diverse sensors in various locations and provides a real-time comprehensive picture of what all the sensors see. Any number of users may tap the integrated data stream and receive this picture simultaneously. The entire system is highly mobile and flexible. Adaptive response to tactical conditions is possible via emission control and rapid relocation of sensor resources. Sensor angle and location diversity minimizes terrain masking and the effectiveness of main beam noise jamming. A netted radar system is operable in all weather in mid Europe, and may be controlled and displayed from any desired remote location over a standard telephone line or voice-grade anti-jam radio link.

This brochure describes the Phase II Netted Radar Demonstration, scheduled for the Fall 1980 at Ft. Sill. A four-radar net will be operated, including two ground-based ground-surveillance radars, an airborne ground-surveillance radar representing a standoff moving-target radar, and a counter-fire radar - the TPQ-36. Six Operational Demonstrations will be performed, in support of NURADS, to illustrate the tactical value of this kind of netting. Multiple user displays will be utilized, including some hand-held militarized display units which are now being produced for another program.

There will also be a demonstration in which the Airborne Radar will be used to show mini-RPV radar capability to detect and track targets which alternately move and stop. In addition, a ground-based Advanced Ground Surveillance Radar will be present for comparison of its performance with that of the modified PPS-5 radars. The AGSR was constructed to show the capability of state-of-the-art technology for this kind of radar application.

The Operational Demonstrations are scheduled from mid-October through mid-November, 1980, to illustrate tactical netted-system potential. Visitor demonstrations are scheduled from about mid-November through mid-December.

There are four key elements in a netted radar system: The Sensors, The Target Integration Center (TIC), the Displays, and the Communications Links. The sensors are able to automatically acquire and track targets, sending the significant data in UTM coordinates over narrowband comm links to the TIC. The TIC automatically integrates sensor data and sends the compacted data over narrowband comm links to users with displays.

The principal benefit of this sort of netted system is that a comprehensive real-time picture of what all the sensors see is available to all the users simultaneously. A specific user may choose to look at only a subset of the total data base, pertinent to his area of interest or mission. Comm links only require standard telephone or field wire lines, or voice-grade radio. A user may be at any distance from the TIC and still receive all data available, if he has a reliable comm link to it. If the comm links are radios, a given user who is closer to a sensor than to the TIC could tune in to its frequency and see data from it, during times he could not receive comm from the TIC because of ECM or difficult terrain.

Other benefits of netting include reduced personnel requirements because of the high degree of system automation; enhanced survivability from component mobility; coordinated net countermeasures such as blinking of sensors; and the ability to acquire and bring fire on additional target types, such as the Shoot-N-Scoot Multiple Rocket Launchers, via the netting of diverse sensor types. Some sensors may be moving to a new location while the net continues operation. Upon arriving at a new location, a sensor automatically surveys its location and attitude, either from known targets already in the net or by other available means, and then immediately begins to contribute data as one of the net sensors.

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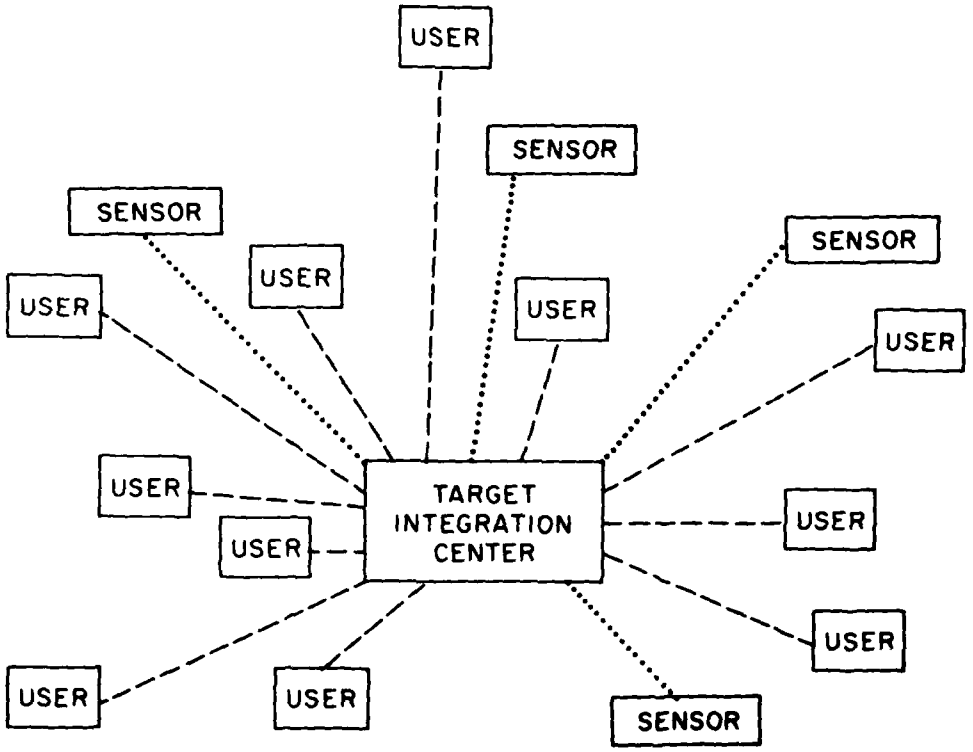
NETTED RADAR SYSTEM - DEFINITION



The Phase I Netted Radar Demonstration was held at Ft. Sill, OK during the period October 1978 - February 1979. The equipment utilized consisted of two modified PPS-5 radars (TPS-5X unofficially) with support vans, VRC-46 radios, a Target Integration Center (called Radar Control Center at that time), and a remote display.

Moving vehicles were tracked at 20 km range; helicopters, walking personnel, activity points, and artillery shellbursts were detected at shorter ranges. Noise jammers were triangulated and their UTM coordinates automatically displayed. Audio doppler signature was used to manually classify target types. Artillery fire was adjusted by observing the position of a shellburst relative to the desired impact point.

System performance generally equalled or exceeded expectations, and resulted in two major accomplishments. First, the improved performance of the TPS-5X radars was clearly demonstrated. All targets within a radar's scan sector were simultaneously and automatically acquired and tracked, and the radars were remotely controlled and displayed over voice-grade radio links. Second, the feasibility of automatic integration of radar data was confirmed, and the basic features of netting were illustrated with a simple two-radar net.

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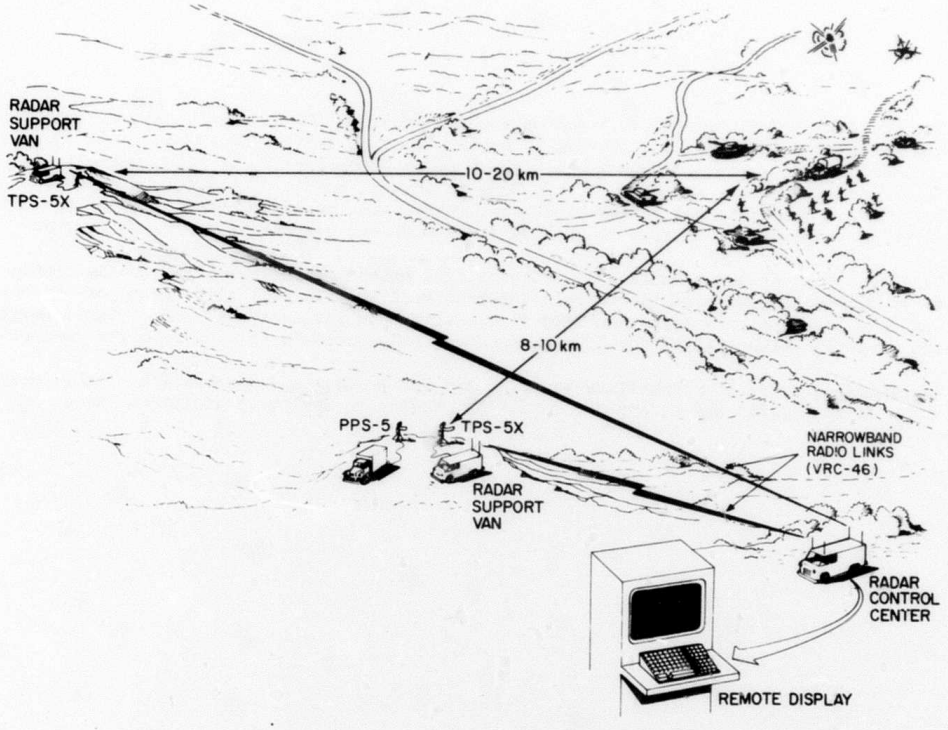

PHASE I DEMONSTRATION AT FT. SILL

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The Phase II Netted Radar Demonstration includes the two TPS-5X radars as well as an Advanced Airborne Radar (ABR) and the TPQ-36 mortar locating radar. Data from these four radars is sent over narrowband comm links (VRC-46 radio, 1200 bps) to the TIC, where it is integrated and sent over a voice-grade wire line to several remote displays in a nearby trailer. Fire missions to and interaction with TACFIRE will be an important part of the Demonstration. Additional details concerning various system components are given further on.

Addition of an Airborne Radar will substantially extend the area visible to the netted sensors by eliminating much of the terrain and tree masking. It will allow study of the issues involved in automatically integrating data from an airborne moving-target radar with a moving platform whose location must be continually updated, and ground-based moving-target radars.

Inclusion of a TPQ-36 counterfire radar in the net permits a demonstration of the benefit of netting diverse radar types, and the resulting ability to deal with additional kinds of targets.

PHASE II NETTED RADAR DEMONSTRATION

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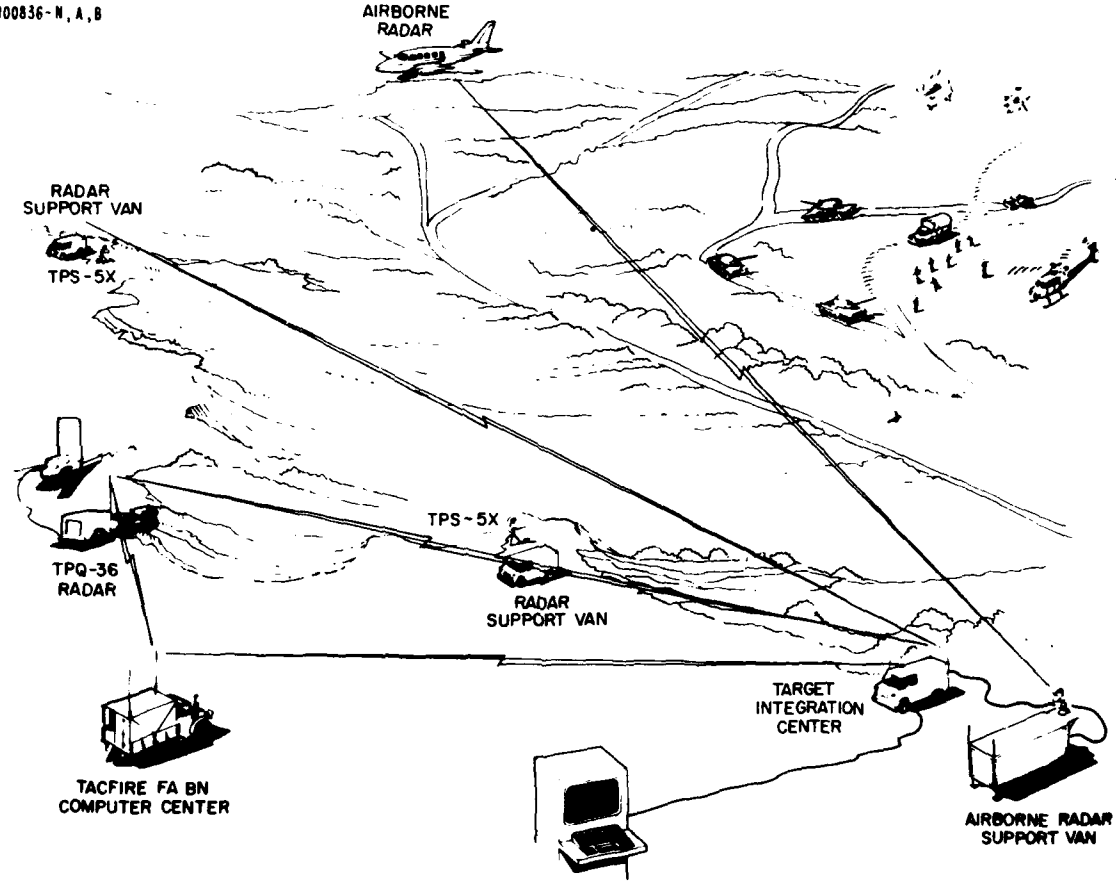

These objectives for the Phase II Netted Radar Demonstration were determined by the Field Artillery School. They are intended to support development of the Army NURADS Program.

The Airborne Radar will be used to represent a standoff moving-target radar at about 20 km range, and to represent a mini-RPV radar at about 3 km range. Inclusion of the TPQ-36 and a data link to the TACFIRE Battalion Computer Center will allow study of the benefits of an integrated target-acquisition/fire-delivery system which is largely automated. This makes possible advanced artillery tactics and capabilities, some of which are to be shown via the Operational Demonstrations planned for Objectives 4A-E. Data which is to be gathered will permit consideration of the utilization of the TIC as a filter for TACFIRE.

In 4A, the netted system ability to bring fire on to a highly mobile indirect-fire weapon, such as a Multiple Rocket Launcher, will be shown. There is no current artillery capability to deal with this target type, although there is increasing emphasis on shooting and moving in modern tactical doctrine.

In 4B, the position of a HELBAT tank moving along a road will be predicted at a future time, assuming that it will continue on the road at a constant speed. A time-on-target fire mission will be initiated with TACFIRE to show the ability to fire on moving targets.

In 4C, a Howitzer will be registered using an impact point about 1 km away from a rotating corner reflector which represents an activity point. A HE round will then be fired at the activity point with the intention of placing it close enough for first-round destruction.

Demonstrations supporting 4D and 4E will be conducted to illustrate the system general surveillance and target acquisition ability, and the degree to which it can classify target types.

More complete descriptions of the Operational Demonstrations are given further on.

PHASE II DEMONSTRATION OBJECTIVES

1. DEMONSTRATE NETTING OF AIRBORNE AND GROUND-BASED MOVING-TARGET RADARS

2. INTEGRATE THE TPQ-36 COUNTERFIRE RADAR

3. DETERMINE THE BEST DATA-FLOW ROUTE BETWEEN THE TPQ-36, TIC, AND TACFIRE

4. ANALYZE SELECTED APPLICATIONS OF COUNTERFIRE/MOVING TARGET DATA
   - A. SHOOT-N-SCOOT TARGET ATTACK
   - B. ATTACK MOVING TARGET ON ROAD
   - C. FIRST-ROUND KILL OF ACTIVITY POINT
   - D. SIMULATED ASSAULT
   - E. ARTILLERY BATTERY PATTERN RECOGNITION

5. DEMONSTRATE DISPLAY OF NETTED SENSOR DATA AT TIC AND AT REMOTE LOCATION FROM TIC

At Ft. Sill, two Active Displays and one Passive Display will be located in a trailer near the TIC van. In addition, an Active Display will be located in the van itself. Active Displays can receive and display data from the TIC, and can command the modes and coverages of the radars (except the TPQ-36 in this instance). They are Megatek black and white vector displays, a photo of which appears on page 7r. Passive Displays can only receive and display the TIC data. The Passive Display will be a hand-held militarized display currently being produced for another program by Litton Data Systems.

It is planned to have one Active Display and one Passive Display at a remote location, e.g. the Pentagon or an Army Facility, to make the Visitor Demonstrations available in real-time to a wider audience.

Each Passive Display has certain limited operator options: zoom, UTM coordinates of screen center, UTM grid on display, and road network background. Each Active Dislay has these and other operator options such as real-time insertion of unit boundary lines or no-fire lines. This data is sent to the TIC, stored there in memory, and passed to all other displays.

The photos at the right show the (off-line-digitized) road network background, the radars' coverage lines, and various target types in track (walking personnel - targets 73 and 90, activity point - target 158, helicopter - target 199, vehicles on Bailey Turnpike - right photo). The upper number in the target tag is the track number; the lower number is the target's current true speed in meters per second.

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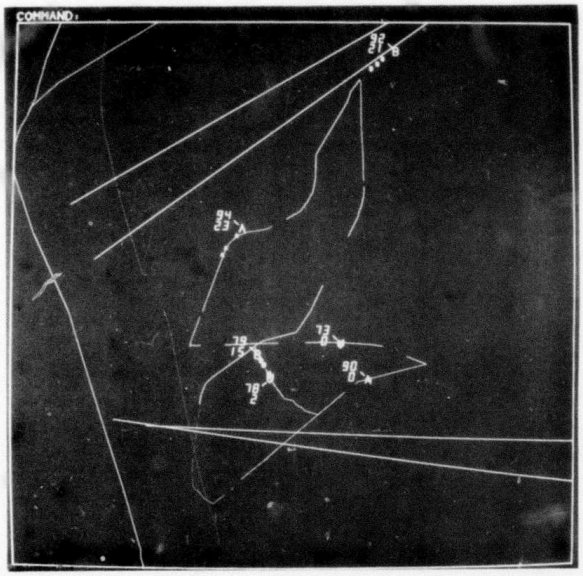
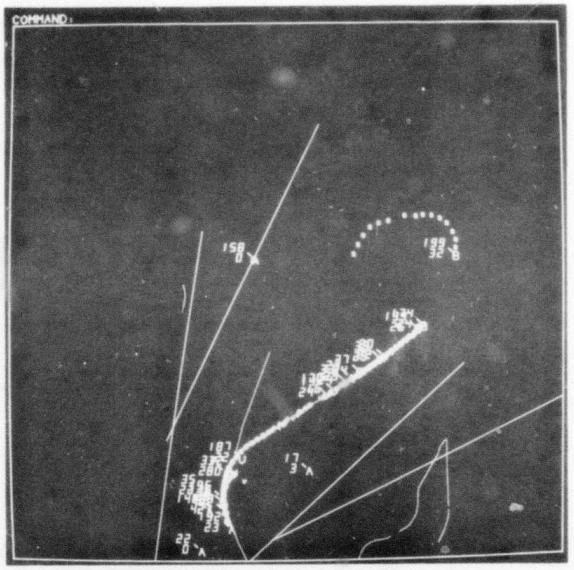




Photos of TIC display

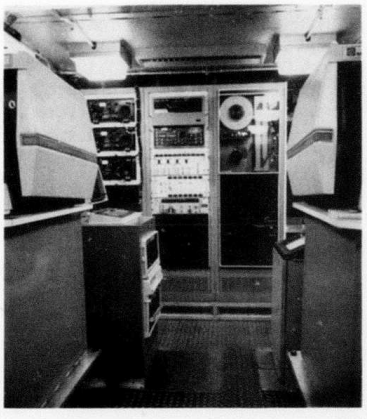
The TIC for the Phase II Demonstration is housed in a van, shown in the photo at the right. This van contains recording and test equipment which would not be part of a militarized TIC. The essence of a militarized TIC would be a computer similar to the Data General Eclipse S/130 (lower left in lower left photo), several radios (upper left in lower left photo), and a display somewhat smaller than the Megatek display shown in the lower right photo.

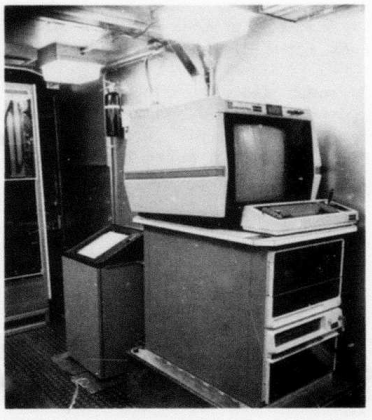
In Phase II, the TICs function is to receive data from the radars, integrate it, and pass it on to the displays. It also transmits commands from any Active Display to the radars, and text messages from any Active Display or radar to any other display or radar. Once on line, it runs automatically, without people present, and permits control and display of the entire netted system from any Active Display.

In addition, the TIC for Phase II has been equipped with a TACFIRE interface. Netted radar message formats (both digital and voice) are automatically converted to TACFIRE formats and vice versa for both transmission and reception of TACFIRE messages. These messages are able to be sent or received at any Active Display.

The TIC has both digital and analog recording and playback capabilities. All digital, voice, or analog messages sent or received during the Operational Demonstrations will be recorded for later analysis.

TARGET INTEGRATION CENTER





The Advanced Airborne Radar (ABR) operates in the frequency range 16.0 - 16.5 GHz. It has a 7 milliradian 2-way azimuth beam, electronically scanned $\pm 30^{\circ}$, and a 2-way vertical beam of about 18°. Data gathered by the radar is sent over a broadband (10 Mbps) link to a ground support van, where it is processed in real-time, reduced to a rate of about 1200 bps, and sent to the TIC. A militarized version of such a radar would have much more data processing on board the aircraft, and a narrowband link to the ground station.

The aircraft has an Inertial Navigation System (INS) which is periodically corrected by data from several Distance Measuring Units (DMUs) on the ground. This equipment determines the accurate location of detected targets and makes possible the reporting of their UTM coordinates to the TIC.

The ABR will be used in Phase II to represent a standoff moving-target radar system, so as to permit study of the issues in integrating airborne and ground based MTI radars. In the standoff moving-target radar mode, it will have a down-look angle of 3° - 6°, and be able to see moving tank-size vehicles at about 20 km range. It will also have a mini-RPV mode, in which it will represent what might be seen with a radar which could be housed and operated in a currently-developing mini-RPV. In this mode, the radar will detect both stationary and moving vehicles at about 3 km range, with a down-look angle of 3°.

This radar and ground support van were originally developed for the HOWLS Program, and used for data gathering and algorithm development. Modifications have been made during the past year or so which permit real-time signal and data processing, and reporting of targets in UTM coordinates over a narrowband link.

Advanced Airborne Radar

The RF (radio frequency) portion of a modified PPS-5 radar (TPS-5X unofficially) is shown at the right. The antenna has a 15 mil 2-way azimuth beamwidth and is mechanically scannable; its elevation beamwidth is 43 mils 2-way. The radar operates in the frequency range 16.0 - 16.5 GHz.

A radar support van is nearby, housing the signal and data processing equipment, a Megatek display, radios, and test and recording equipment. The militarized version of this equipment would be small enough and light enough to be readily carried in the rear of a 1/4T truck. A mockup of this equipment has been constructed.

The TPS-5X radar is able to detect and track moving tank-size targets at about 20 km range. Its azimuth scan is variable from 0° to about 90° and it scans at the rate of 18° per second. Its range scan sector is variable from 50m to 16 km, with its processing designed for a minimum range of about 1 km and a maximum range of 30 km. Modern digital processing enables the system to automatically detect and track simultaneously all targets within its scan sector. In addition to moving vehicles, it can detect low-flying aircraft, rotating radar antennas, moving personnel, activity points, artillery shellbursts, and azimuths of noise jammers. Ten histories are kept on each track.

Several kinds of activity maps are also kept by the radar, for each 500m x 500m sector in the scan coverage. Data is compiled on (1) the number of single-scan detections, with a 10-minute fading memory; (2) the single-scan detections which are not used in forming track files; (3) the number of track files active; (4) the number of track files terminated. These data are sent over the radar's narrowband comm link to the TIC together with the usual target track file reports. Alternatively, the radar may be instructed to send the activity maps together with all single-scan detections in its scan sector.

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TPS-5X radar on Mt. Scott, OK, looking over Ft. Sill

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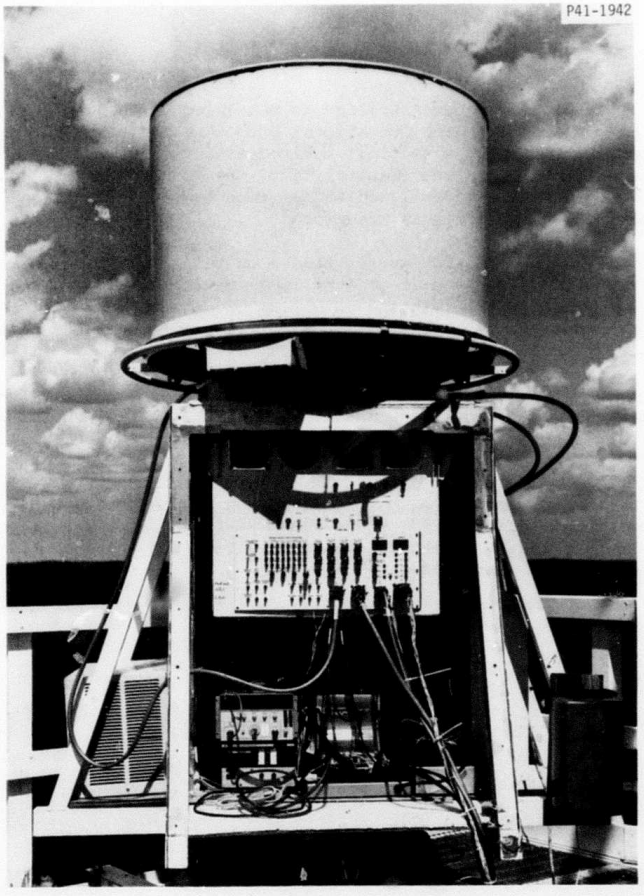
During the past two years, work has progressed on a new ground-based Advanced Ground Surveillance Radar (AGSR). A brassboard version of this radar operates in the frequency range 5.25 to 5.65 GHz. Its antenna is a cylindrical array electronically steerable over 360° in azimuth. This permits it to simultaneously support all the modes which the TPS-5X radar can only utilize sequentially.

The AGSR was built to demonstrate what modern technology could achieve in realizing a high-performance high-ECCM ground surveillance radar. It is not formally a part of the Phase II Netted Radar Demonstration, but will be tested at Ft. Sill during the same period as a stand-alone radar. A remote display will permit a convenient comparison of its performance with that of the TPS-5X radars.

Antenna beamwidth is 55 mils two-way in azimuth. Elevation beamwidth is 60 mils two-way, with a -10 dB shoulder extending out another 60 mils or so for low-altitude high-performance aircraft detection and tracking. The radar has several important ECCM features, including low azimuth sidelobes, random frequency hopping, and tapered pulses. Its data output format is similar to that of the TPS-5X, and it is capable of being remotely controlled and displayed in netted operation over a narrowband comm link.

The brassboard version of the radar will be mounted on top of its support van, which houses the signal and data processing equipment, a Megatek display, and recording equipment. It will automatically detect and track moving targets in several operator-specifiable areas of interest at independently-selectable update rates, while detecting shellbursts in other areas, and passively determining the azimuth bearings of noise jammers. Alternatively, the AGSR can be operated in its low-altitude aircraft detection mode. In a tactical version, this mode would operate simultaneously with the ground-surveillance modes.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The Phase II Netted Radar Demonstration is scheduled to be completed in December 1980. A report is to be prepared for each Operational Demonstration, summarizing the findings and its potential for implementation in a tactical environment. It is expected that the results of the Phase II Demonstration will confirm feasibility of the NURADS concept, and show some of its benefits. However, there are several additional important considerations which have to be addressed as the procurement cycle is traversed.

Further testing is needed with more emphasis on using the Netted Radar equipment in simulated tactical situations, such as in an Army field exercise. This would allow Army personnel to operate the equipment, and permit the gathering of data to formulate the best Operational and Organizational concept. An additional possibility is to test the equipment in support of peacetime monitoring of borders between countries.

Effort is required on examining the critical issues related to implementation of NURADS. Questions about which users should get what data, reliable anti-jam comm links, algorithms to automatically recognize target types, etc., are important to a successful cost-effective procurement and utilization.

Looking more toward the future, one can envision expanding the NURADS-proposed net to include such sensors as the mini-RPV, sound-flash units, artillery FOs, possibly REMBASS, and others. Which sensors should be netted, in what manner, and what benefits are to be realized, are issues which need to be studied.

CONSIDERATIONS IN IMPLEMENTATION OF NURADS

- OPERATIONAL TESTING OF SYSTEM FUNCTIONS IN ARMY FIELD EXERCISES UNDER VARIOUS CONDITIONS
- RESOLUTION OF CRITICAL ISSUES IN TACTICAL IMPLEMENTATION
- STUDY OF WHICH ADDITIONAL SENSOR SYSTEMS OUGHT TO BE INCLUDED IN THE NET

OPERATIONAL DEMONSTRATIONS

1. MINI-RPV RADAR UTILIZATION

Objective:
To demonstrate the all-weather stationary and moving target location capabilities of a real-aperture mini-RPV radar, and the continuity of track of targets which alternately stop and move.

Overview:
The Airborne Radar will be flown in a "square" pattern, keeping a 2 km^2 area under constant surveillance at a range of about 2.5 km. This simulates what might be done with a real-aperture mini-RPV radar such as could be carried by a currently-developing mini-RPV.

A convoy of vehicles will move within the surveillance area, occasionally stopping for short periods. The Airborne Radar will detect the vehicles both when they are moving and when they are stopped, and report their coordinates to the TIC van. The Active Display Observers will determine the conditions under which it is possible to manually maintain target track continuity, and the utility of the data for military purposes.

2. ARTILLERY BATTERY PATTERN RECOGNITION

Objective:
To determine the feasibility of recognizing a field artillery battery moving into a position by observation with a ground surveillance radar.

Overview:
RSOP (reconnaissance, selection, and occupation of position) exercises will be observed at Ft. Sill with a TPS-5X radar, utilizing the activity cluster mode. Ground truth will be recorded by an observer at the RSOP site and compared with the situation deduced by the Active Display Observers from the Active Display.

3. SIMULATED ASSAULT

Objectives:

To determine the ability of the Netted Radar system to detect and classify helicopters, vehicles, and personnel in a simulated assault scenario.

Overview:

A simulated FEBA will be specified, with the two TPS-5X radars and the Airborne Radar located on the one side looking toward the other. Several convoys consisting of helicopters, vehicles, and personnel will approach the FEBA from the enemy side. The Netted Radar system will be scanning this area to detect and, to the extent possible, classify target types in the approaching force. The Active Display Operator will simulate sending fire missions to TACFIRE and helicopter warning information to the Executive C^2 system.

4. ATTACK MOVING TARGET ON ROAD

Objectives:

A. To demonstrate the ability to attack a target moving on a road with radar and field artillery, using a time-on-target (TOT) procedure.

B. To demonstrate the ability to attack a target moving on a road with radar and field artillery, using an at-my-command (AMC) procedure.

C. To demonstrate the ability to attack a moving target stopped by FASCAM, using radar and field artillery.

Overview:

A 155mm Howitzer will be registered by one of the TPS-5X radars, using the procedure described in Operational Demonstration No. 7. Sometime afterward, a HELBAT tank will begin to move along a predetermined cleared road in an Impact Area. The tank will be tracked by the radar.

For Objective A, the Active Display Operator (ADO) will initiate a TOT fire mission with TACFIRE. At the specified time, an inert HELBAT round will be fired by the Howitzer at the estimated tank position. The radar will detect the round impact and report its location relative to the actual tank location.

For Objective B, the procedure is the same except that the ADO will initiate an AMC fire mission with TACFIRE.

For Objective C, A FASCAM distribution will be simulated, and the moving target fired upon when it stops at the FASCAM obstacle.

OPERATIONAL DEMONSTRATIONS (continued)

5. FIRST ROUND KILL OF ACTIVITY POINT

Objective:

To demonstrate ability to use radar and a previously-registered Howitzer to direct fire at an activity point with sufficient accuracy for first round kill.

Overview:

A 155mm Howitzer will be registered by one of the TPS-5X radars, using the procedure described in Operational Demonstration No. 7. A Moving Target Simulator (MTS), representing an Acitvity Point, about 1 km from the registration point, will then be turned on and tracked by the radar. The Active Display Operator (ADO) will initiate a fire mission to TACFIRE, and the Howitzer will fire one HE round at the MTS with the goal of first-round kill. A first-round impact which is close enough will knock over or destroy the MTS, causing its track to disappear from the Active Display.

6. SHOOT-N-SCOOT TARGET ATTACK

Objectives:

To demonstrate the ability to attack a hostile indirect-fire weapon which fires and quickly moves to another location before it can be fired upon. Three distinct data-flow arrangements will be tested to determine which is quickest and most convenient.

A. Targeting data will flow from the TPQ-36 radar to the TIC and then to TACFIRE.

B. Targeting data will flow from the TPQ-36 radar to TACFIRE and then to the TIC.

C. Targeting data will flow from the TPQ-36 radar to TACFIRE and the TIC simultaneously.

Overview:

A 155mm Howitzer will fire a round which will be detected by the TPQ-36 radar. The location of the Howitzer will be reported to the TIC and shown on the Active Display. X minutes after the TPQ-36 reports, a tracked vehicle, parked near it, will begin to move to a new firing point. This represents the Howitzer moving shortly after firing. X will have values of 1, 3, 5 in different tests.

A soon as the TPQ-36 reports the location of the Howitzer, a fire mission will be initiated through TACFIRE. However, before the mission can be executed, the simulated Howitzer movement occurs. The movement is tracked by the Airborne ground-surveillance radar and shown on the Active Display. The Active Display Operator (ADO) correlates the track with the marked Howitzer location and cancels the fire mission to TACFIRE.

The tracked vehicle, representing the Howitzer, will move about 1 km to a new firing point and stop. At that time, the ADO will initiate a new fire mission to TACFIRE. This demonstation will be run several times with targeting data routed differently, as described under Objectives above.

7. *REGISTRATION OF HOWITZER WITH MTI RADAR*

Objectives:

To register fire from a Howitzer using shellburst detection with an MTI radar.

Overview:

TACFIRE will request the TIC to observe shellbursts at vicinity of specified coordinates, for the purpose of registering fire from a Howtizer. The Active Display Operator will note the centroid of the last three shellbursts of the group fired, and report it to TACFIRE.